

Sickle Cell Trait and Other Hemoglobinopathies and Diabetes: Important Information for Providers

National Diabetes Information Clearinghouse



The hemoglobin A1C (A1C) test can be unreliable for diagnosing or monitoring diabetes and prediabetes in people with inherited hemoglobin variants, also called hemoglobinopathies. Hemoglobins S and E are prevalent variants in people of African, Mediterranean, or Southeast Asian descent. These variants interfere with some A1C tests—both laboratory and point-of-care tests. If A1C tests are at odds with blood glucose testing results, interference should be considered. Reliable A1C tests that do not cause interference with hemoglobin variants are available. More information about appropriate assay methods to use for hemoglobin variants is available from the NGSP at www.ngsp.org. Also, alternative tests may be needed for people with any disorder that affects red blood cells or hemoglobin.

When to Suspect That a Patient with Diabetes Has a Hemoglobinopathy

Most people who are heterozygous—having one variant gene and one standard hemoglobin gene—for a hemoglobin variant have no symptoms and may not know that they carry this type of hemoglobin. Health care providers should suspect the presence of a hemoglobinopathy when

- an A1C result is different than expected
- an A1C result is above 15 percent
- results of self-monitoring of blood glucose have a low correlation with A1C results
- a patient's A1C result is radically different from a previous A1C result following a change in laboratory A1C methods

Statistically Speaking

Hemoglobins S and C

African Americans have an increased risk of inheriting sickle cell trait, the condition in which people have both hemoglobin A (HbA), the usual form of hemoglobin, and hemoglobin S (HbS), a variant. African Americans are also at risk for having hemoglobin C (HbC), another variant. About one in 12 African Americans has sickle cell trait. About 13 percent of African Americans ages 20 years or older have diabetes.¹ Therefore, many African Americans have both diabetes and sickle cell trait.

Hemoglobin E

People of Southeast Asian descent are at risk for having hemoglobin E (HbE), another hemoglobin variant. Prevalence of diabetes in Asian Americans varies among subpopulations. About 9 percent of Asian Americans ages 20 years or older have diabetes.¹

Hemoglobinopathies

Hemoglobin is composed of heme—the portion of the molecule containing iron—and globin—a protein made up of amino acid chains. Hemoglobin variants occur when mutations in the globin genes result in changes in the amino acids of the globin protein. Hundreds of variants have been identified; a small number of variants are common and have clinical significance. Variants significant to A1C testing are listed in Table 1.

These variants are inherited in an autosomal recessive manner, affecting people in the following ways. People who are

- homozygous, with a condition such as hemoglobin SS (HbSS), have a copy of the variant gene from each parent and generally have sickle cell disease.
- heterozygous, with a condition such as hemoglobin S (HbS), have a copy of the variant gene from one parent and are said to have a trait or to be carriers and are usually asymptomatic.
- compound heterozygous, with a condition such as hemoglobin SC (HbSC), have inherited genes for two variants—HbS from one parent and HbC from the other. These patients may have less severe sickle cell symptoms.

¹National diabetes statistics report, 2014. Centers for Disease Control and Prevention website. www.cdc.gov/diabetes/pubs/statsreport14.htm. Updated June 13, 2014. Accessed June 16, 2014.

Detecting Hemoglobinopathies

If a health care provider suspects that a patient may have a hemoglobinopathy, carrier status can be detected using hemoglobin electrophoresis, high-performance liquid chromatography (HPLC), or isoelectric focusing.

Alternatively, a health care provider can use an assay that does not have interference with any variant. See “Information about Assay Methods for Patients with Hemoglobinopathies.”

Technically Speaking...

The A1C test measures the amount of glycated hemoglobin in the blood, which reflects average blood glucose levels over the preceding 3 months. Also called the hemoglobin A1C, HbA1c, or glycohemoglobin test, the A1C test is based on the addition of glucose to hemoglobin over the typical 120-day life span of a red blood cell.

Formation of glycated proteins is proportional to the concentration of glucose in the blood. However, the A1C test is a weighted average, with the glucose level of the preceding 30 days contributing more to the test result than glucose levels 90 to 120 days earlier. Thus, clinically significant changes in glucose can be seen in the A1C without waiting 120 days for red blood cell turnover.

When the A1C test is used for diagnosis, the blood sample must be sent to a laboratory that uses an NGSP-certified method for analysis to ensure the results are standardized.

More information for health care providers about the A1C test can be found in the following National Diabetes Information Clearinghouse (NDIC) fact sheets at www.diabetes.niddk.nih.gov:

- *The A1C Test and Diabetes*
- *Comparing Tests for Diabetes and Prediabetes: A Quick Reference Guide*

Effect of Hemoglobinopathies on A1C Test Results

Laboratories use many different assay methods for measuring A1C, but some of these methods can give inaccurate results when the patient has a hemoglobin variant such as sickle cell trait or if there is an elevated level of HbF. Health care providers or patients interested in getting information about the accuracy of a particular A1C method for patients with hemoglobin variants should first find out which method their laboratory is using.

With some assay methods, A1C tests in patients with hemoglobinopathies result in falsely high outcomes, overestimating actual average blood glucose levels for the previous 3 months. Health care providers may then falsely diagnose patients or prescribe more aggressive treatments, resulting in increased episodes of hypoglycemia. Some methods used with certain hemoglobinopathies may result in falsely low outcomes, leading to undertreatment of diabetes.

Health care providers should not use the A1C test for patients with a disease condition such as HbSS, HbCC, or HbSC. Even if an assay does not interfere with their variant, these patients may suffer anemia, increased red blood cell turnover, and transfusion requirements, which can adversely affect A1C as a marker of long-term glycemic control.

See “Other Conditions That Can Affect A1C Test Results” for information about other conditions that may give false test results. Health care providers should consider alternative forms of testing for these patients, such as glycated serum protein or glycated albumin.

Common Types of Hemoglobinopathies

The following table summarizes the affected populations, prevalence, and outcomes of common hemoglobinopathies. These hemoglobinopathies may either falsely raise or lower A1C results, depending on the variant and the assay method.

Table 1. Common hemoglobinopathies: populations affected, prevalence, and outcomes

Hemoglobin Variant	Populations Affected	Prevalence (in the United States unless otherwise noted)	Outcome with One Abnormal Gene and One Normal Gene (Heterozygous State)	Outcome with Two Abnormal Genes (Homozygous State)
HbS	African Americans Hispanics/Latinos Also found in Africa, South or Central America (especially Panama), Caribbean islands, Mediterranean countries (such as Turkey, Greece, and Italy), India, and Saudi Arabia	About one in 12 African Americans has sickle cell trait. ² About one in 100 Hispanics/Latinos has sickle cell trait. ² Sickle cell anemia occurs in one of every 500 African American births. ² Sickle cell anemia occurs in one of every 36,000 Hispanic/Latino births. ²	Sickle cell trait (also called HbAS): usually asymptomatic	Sickle cell anemia (also called HbSS disease): sickled red blood cells that interfere with circulation and decrease life span of red blood cells; can result in hemolytic, splenic sequestration, and aplastic crises and multiple complications
HbC	African Americans People of West African descent	About 2.3 percent of African Americans have HbC trait. ³	HbC trait (also called HbAC): asymptomatic	HbC disease (also called HbCC disease): mild hemolytic anemia, mild to moderate enlargement of the spleen

²What Is Sickle Cell Anemia? National Heart, Lung, and Blood Institute website. www.nhlbi.nih.gov/health/dci/Diseases/Sca/SCA_WhatIs.html. Posted February 1, 2011. Accessed July 27, 2012.

³Bry L, Chen PC, Sacks DB. Effects of hemoglobin variants and chemically modified derivatives on assays for glycohemoglobin. *Clinical Chemistry*. 2001;47(2):153–163.

Hemoglobin Variant	Populations Affected	Prevalence (in the United States unless otherwise noted)	Outcome with One Abnormal Gene and One Normal Gene (Heterozygous State)	Outcome with Two Abnormal Genes (Homozygous State)
HbE	<p>Asian Americans, especially those of Southeast Asian descent</p> <p>Common in Cambodia, Indonesia, Laos, Malaysia, Thailand, and Vietnam</p> <p>Also seen in southern China, India, the Philippines, and Turkey</p>	Prevalence of HbE may be 30 percent in Southeast Asia. ³	HbE trait (also called HbAE): asymptomatic	HbE disease (also called HbEE disease): mild hemolytic anemia, microcytosis, and mild enlargement of the spleen
HbSC	<p>African Americans and people of West African descent</p> <p>Also found in East India, the Mediterranean, and the Middle East</p>	N/A	N/A	HbSC disease (also called sickle-hemoglobin C disease): mild hemolytic anemia and moderate enlargement of the spleen; may have blocking of blood vessels as in sickle cell anemia but milder symptoms
HbF elevated	Occurs in patients with hereditary persistence of fetal hemoglobin, sickle cell anemia, severe anemias, leukemia, and other conditions	About 1.5 percent have more than 2 percent HbF, but some groups may have concentrations as high as 12 percent. ³	N/A	Those with elevated HbF and sickle cell anemia may have a milder form of sickle cell anemia.

Information about Assay Methods for Patients with Hemoglobinopathies

The NGSP provides a table on its website at www.ngsp.org describing the effects of frequently encountered Hb variants and derivatives on glycohemoglobin measurement for more than 20 assay methods. The NGSP website also includes a list of references for the information summarized in the table.

The NGSP has worked with manufacturers and developed a network of reference laboratories to ensure the availability of assay methods without clinically significant HbAS or HbAC interference. In 2011, per the NGSP website, only about 4.2 percent of laboratories were using methods resulting in significant HbAS or HbAC interference. See www.ngsp.org for updates.

Alternative Tests

Health care providers may wish to consider using other measures of average blood glucose levels, such as the fructosamine test, also called glycated serum protein or glycated albumin, with patients who have hemoglobinopathies where an accurate A1C result cannot be obtained. However the fructosamine test shows average glucose levels over a much shorter period of time than the A1C test, usually about 2 to 3 weeks. Also, the fructosamine test is not standardized and the relationship of results of this test to glucose levels or risk for complications has not been established.

Other Conditions That Can Affect A1C Test Results

False A1C results may also occur in people with other problems that affect their blood or hemoglobin, regardless of which assay is used. For example, a falsely low A1C result can occur in people with

- anemia
- heavy bleeding

A falsely elevated A1C result can occur in people who

- are very low in iron, for example, those with iron deficiency anemia

Other causes of false A1C results include

- kidney failure
- liver disease

A booklet is available for patients with diabetes about hemoglobin variants and the A1C test. *For People of African, Mediterranean, or Southeast Asian Heritage: Important Information about Diabetes Blood Tests* is provided by the NDIC at www.diabetes.niddk.nih.gov.

Points to Remember

- The hemoglobin A1C (A1C) test can be unreliable for diagnosing or monitoring diabetes and prediabetes in people with inherited hemoglobin variants, also called hemoglobinopathies.
- Hemoglobins S and E are prevalent variants in people of African, Mediterranean, or Southeast Asian descent. These variants interfere with some A1C tests—both laboratory and point-of-care tests.
- With some assay methods, A1C tests in patients with hemoglobinopathies result in falsely high outcomes, overestimating actual average blood glucose levels for the previous 3 months. Health care providers may then falsely diagnose patients or prescribe more aggressive treatments, resulting in increased episodes of hypoglycemia.
- Some methods used with certain hemoglobinopathies may result in falsely low outcomes, leading to undertreatment of diabetes.
- Most people who are heterozygous—having one variant gene and one standard hemoglobin gene—for a hemoglobin variant have no symptoms and may not know that they carry this type of hemoglobin.
- Health care providers should suspect the presence of a hemoglobinopathy when
 - an A1C result is different than expected
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 - results of self-monitoring of blood glucose have a low correlation with A1C results
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- Health care providers or patients interested in getting information about the accuracy of a particular A1C method for patients with hemoglobin variants should first find out which method their laboratory is using.
- Reliable A1C tests that do not cause interference with hemoglobin variants are available.
- When the A1C test is used for diagnosis, the blood sample must be sent to a laboratory that uses an NGSP-certified method for analysis to ensure the results are standardized.
- Health care providers should not use the A1C test for patients with a disease condition such as HbSS, HbCC, or HbSC. Even if an assay does not interfere with their variant, these patients may suffer anemia, increased red blood cell turnover, and transfusion requirements, which can adversely affect A1C as a marker of long-term glycemic control.
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Hope through Research

The National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK) conducts and supports research related to the causes, treatment, and prevention of diabetes. The NIDDK also supports several programs and studies devoted to improving treatment for patients with sickle cell disorders. The High Throughput Screening of Compound Libraries to Discover a Drug for the Treatment of Sickle Cell Disease study, funded under National Institutes of Health (NIH) clinical trial number NCT00542230, is investigating advances and potential new medication treatments for sickle cell disease. The study is collecting blood samples from healthy children and adults and from children and adults who have unique red blood cell features that are related to sickle cell disease.

The Screening of Subjects to Determine Eligibility to Safely Participate in Blood Disorders Studies, funded under NIH clinical trial number NCT00695123, will determine eligibility for participation in research studies on blood disorders conducted by the National Heart, Lung and Blood Institute (NHLBI) and the NIDDK. The study is recruiting healthy volunteers, patients with blood disorders who currently participate in NHLBI and NIDDK studies, and potential stem cell donors for patients with blood disorders who are 8 years of age and older to see if they may be eligible for a screening protocol.

Clinical trials are research studies involving people. Clinical trials look at safe and effective new ways to prevent, detect, or treat disease. Researchers also use clinical trials to look at other aspects of care, such as improving the quality of life for people with chronic illnesses. To learn more about clinical trials, why they matter, and how to participate, visit the NIH Clinical Research Trials and You website at www.nih.gov/health/clinicaltrials. For information about current studies, visit www.ClinicalTrials.gov.

For more information about the NIDDK's research on diabetes and related topics, see www.diabetes.niddk.nih.gov/diabetesresearch/dm_research.aspx.

For More Information

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The National Diabetes Education Program is a federally funded program sponsored by the U.S. Department of Health and Human Services' National Institutes of Health and the Centers for Disease Control and Prevention and includes over 200 partners at the federal, state, and local levels, working together to reduce the morbidity and mortality associated with diabetes.

You may also find additional information about this topic by visiting MedlinePlus at www.medlineplus.gov.

This publication may contain information about medications and, when taken as prescribed, the conditions they treat. When prepared, this publication included the most current information available. For updates or for questions about any medications, contact the U.S. Food and Drug Administration toll-free at 1-888-INFO-FDA (1-888-463-6332) or visit www.fda.gov. Consult your health care provider for more information.

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